A STUDY ON MECHANICAL BEHAVIOR OF SURFACE MODIFIED NATURAL FIBER BASED POLYMER COMPOSITES

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR THE DEGREE OF

BACHELOR OF TECHNOLOGY
IN
MECHANICAL ENGINEERING

BY

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CERTIFICATE

This is to certify that the thesis entitled "**A Study on Mechanical Behavior of Surface Modified Natural Fiber Based Polymer Composites"** submitted by **Soumya Ranjan Sethy (Roll: 107ME038)** in partial fulfillment of the requirements for the award of ***Bachelor of Technology*** in the department of Mechanical Engineering, National Institute of Technology, Rourkela is an authentic work carried out under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to elsewhere for the award of any degree.

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A C K N O W L E D G E M E N T

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ABSTRACT

In recent years, natural fiber reinforced polymer composites have received much attention because of their many advantages such as lightweight, nonabrasive, nontoxic, low cost and biodegradable properties. A lot of research has been done all over the world on the use of natural fibers as a reinforcing material for the preparation of various types of composites. However, due to the incompatibility between fibers and polymer matrices, the tendency to form aggregates during processing and the poor resistance to moisture, reduce the use of natural fibers as reinforcements in polymers. Chemical treatments of the natural fiber can clean the fiber surface, stop the moisture absorption process, chemically modify the surface, and increase the surface roughness. To this end, in the present research work, the use of pretreated natural fibers in polymer matrix composites has been studied. Also, the effect of surface modification of natural fibers on the mechanical properties of bamboo fiber reinforced polymer composites has also been discussed. Finally, the surface morphology of the composite of fractured surface is analyzed using SEM study.

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CHAPTER 1

INTRODUCTION

1.1 Background

Recently, composite materials have successfully substituted the traditional materials in several light weight and high strength applications. The reasons why composites are selected for such applications are mainly their high strength-to-weight ratio, high tensile strength at elevated temperatures, high creep resistance and high toughness. By definition composites are materials consist of two or more chemically distinct constituents on a macro scale having a distinct interface separating them and having bulk behavior which is considerably different from those of any of the constituents. The primary phase of composite material having a continuous character is called matrix. Matrix is usually less hard and more ductile. The matrix forms the bulk part. The secondary phase is a discontinuous form is embedded in the matrix. The dispersed phase is generally harder as compared to the continuous phase and is called reinforcement. It serves to strengthen the composites and improves the overall mechanical behaviour of the matrix. A synergism produces material properties unavailable from the individual constituent materials, while a wide range of matrix and strengthening materials gives an option to the product designer allows the designer to choose an optimum combination.

Depending on the type of matrix materials used composite materials can be classified into three categories such as metal matrix composites, polymer matrix composites and ceramic matrix composites. Each type of composite material is suitable for different applications. Most commonly used matrix material in composite materials is polymer. The reason for this is two folds. Firstly, their strength and stiffness are less as compared to ceramics and metal and these shortcomings are overcome by reinforcing other materials with polymers.

Secondly, the processing of polymer matrix composite does not require high pressure and high temperature. For these reasons polymer matrix composites are developing rapidly and soon becoming popular for structural applications. There are two major classes of polymers used as matrix materials such as thermoplastics and thermosets. Thermoplastics (polypropylene, nylons, acrylics etc.), can be repeatedly softened and re-formed by application of heat. However, thermosets (phenolics, epoxies etc.) on the other hand, are materials that undergo a curing process during part fabrication, after which they are rigid and cannot be re-formed. Among them epoxy is the most widely used matrix due to its advantages like good adhesion to other materials, good mechanical properties, good electrical insulating properties, good chemical and environmental resistance etc.

Fiber reinforced polymer composites have played a significant role for a long time in a range of applications for their high specific strength and modulus. These materials also provide lightweight, high durability and design flexibility, which make them attractive materials as comparison to others to use in various applications. Fiber reinforced polymer matrix composites consisting of reinforcing fibres embedded in a rigid polymer matrix. The properties of matrix, fiber and its interface have greatly influencing the properties of composite materials.

Nature continues to offer mankind generously with all kinds of rich resources in ample profusion, such as natural fibres from a huge number of plants. The idea of using cellulose fibers as reinforcement in composite materials is not a new or recent one. Man had used this idea for a long time, since the beginning of our civilization when grass and straw were used to reinforce mud bricks. Since the last decade, a great deal of emphasis has been focused on the development and application of natural fibre reinforced composite materials in many industries. Advantages of natural fibers over man-made fibers include low density, low cost, recyclability and biodegradablility [1-3]. These advantages make natural fibers potential replacement for glass fibers in composite materials.

The natural fibers are consisting of cellulose, hemi-cellulose, lignin, pectin, waxes and water soluble substances. The chemical composition of natural fibers may differ with the growing condition and test methods even for the same kind of fiber. Cellulose is a semicrystalline polysaccharide made up of Dglucopyranose units linked together by *b*-(1-4)-glucosidic bonds [4]. When used to reinforce hydrophobic matrices, due to the large amount of hydroxyl group in cellulose gives natural fiber hydrophilic properties leads to poor interface and poor resistance to moisture absorption [5]. Hemi-cellulose is strongly bound to cellulose fibrils presumably by hydrogen bonds. Hemi-cellulosic polymers are branched, fully amorphous and have a significantly lower molecular weight than cellulose. Hemi-cellulose is partly soluble in water and hygroscopic due to its open structure containing many hydroxyl and acetyl groups [6]. Lignins are highly complex, amorphous, mainly aromatic, polymers of phenylpropane units [4] but have the least water sorption of the natural fiber components [6]. The compositions of few natural fibers are given in Table 1.1.

Table 1.1 Composition of few natural fibers [7, 8]

Natural Fiber	Cellulose (%)	Lignin (%)	Pentosans (%)	Ash (%)
Coir	43	45	-	-
Banana	65	5	-	-
Sisal	47-62	7-9	21-24	0.6-1
Jute	41-48	21-24	18-22	0.8
Bamboo	26-43	21-31	15-26	1.7-5
Kenaf	44-57	15-19	22-23	2-5
Cotton	85-90	0.7-1.6	1.3	0.8-2
Wood	40-45	26-34	7-14	<1

According to the source of origin, natural fibers can be classified into three categories such as animal fiber, vegetable fiber and mineral fibers. The detailed classification of natural fibers is shown in Figure 1.2.

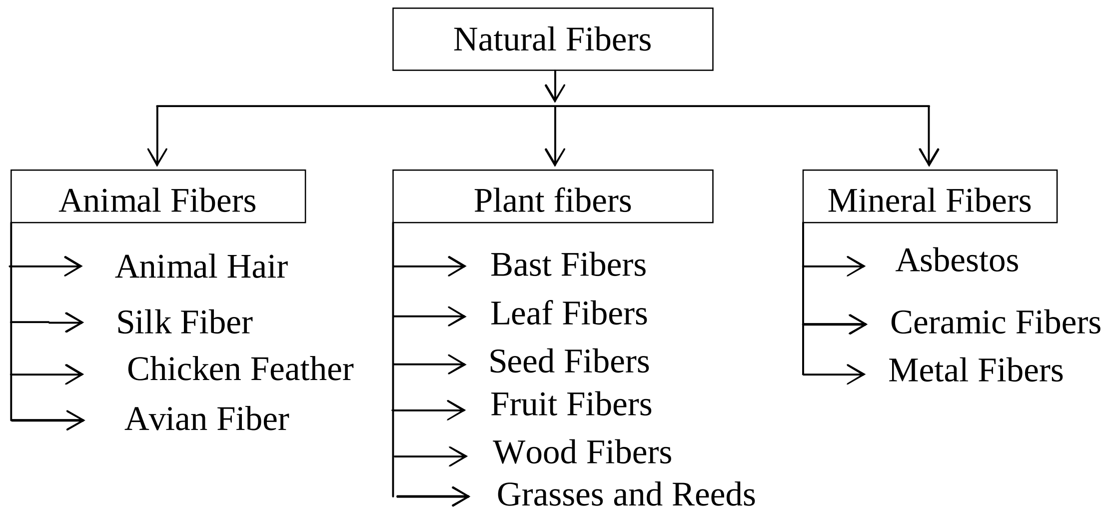

Figure 1.1 Classification of natural fibers

Table 1.2 Properties of natural fibers [9]

Fiber	Tensile strength (MPa)	Young's modulus (GPa)	Elongation at break (%)	Density (g/cm^3)
Abaca	400	12	3-10	1.5
Alfa	350	22	5.8	0.89
Bagasse	290	17	-	1.25
Bamboo	140-230	11-17	-	0.6-1.1
Banana	500	12	5.9	1.35
Coir	175	4-6	30	1.2
Cotton	287-597	5.5-12.6	7-8	1.5-1.6
Curaua	500-1,150	11.8	3.7-4.3	1.4
Date palm	97-196	2.5-5.4	2-4.5	1-1.2
Flax	345-1,035	27.6	2.7-3.2	1.5
Hemp	690	70	1.6	1.48
Henequen	500 ± 70	13.2 ± 3.1	4.8 ± 1.1	1.2
Isora	500-600	-	5-6	1.2-1.3
Jute	393-773	26.5	1.5-1.8	1.3
Kenaf	930	53	1.6	-
Nettle	650	38	1.7	-
Oil palm	248	3.2	25	0.7-1.55
Piassava	134-143	1.07-4.59	21.9-7.8	1.4
Pineapple	400-627	1.44	14.5	0.8-1.6
Ramie	560	24.5	2.5	1.5
Sisal	511-635	9.4-22	2.0-2.5	1.5
E-Glass	3400	72	-	2.5

The properties of some of these fibers are presented in Table 1.2. As can be seen from Table 1.2, the tensile strength of glass fiber is substantially higher than that of natural fibers even though the modulus is of the same order. However, when the specific modulus of natural fibers (modulus/specific gravity) is considered, the natural fibers show values that are comparable to or better than those of glass fibers. These higher specific properties are the major advantages of using natural fiber composites for applications wherein the desired properties also include weight reduction.

Studies on plastics and cements reinforced with natural fibers such as jute, sisal, coir, pineapple leaf, bamboo, banana, sun hemp, straw, and wood fibers have been reported [10-17]. Among the natural fibers, bamboo finds widespread use in housing construction around the world, and is considered as a promising housing material in underdeveloped and developed countries. Bamboo, a naturally occurring composite material, abundantly grows in most of the tropical countries, which is extensively used in construction, agriculture, and chemical industry. Currently, the total bamboo forest area in the world has reached 22 million hectares. The worldwide availability of bamboo fiber is over 30 million tons per year [18]. Over 80% of this resource is distributed in Asian countries, especially in India and China. Bamboo shows mechanical properties comparable to those of wood in general, but grows to maturity in only 6-8 months. As compared to other natural fibers such as sisal, banana, vakka etc. bamboo fiber shows better mechanical properties [19]. Bamboo fibers have emerged as a renewable and cheaper substitute for synthetic fibers such as glass, carbon etc. which are used as reinforcement in making structural components. They have high specific properties such as stiffness, impact resistance, modulus and flexibility and are comparable to those of glass fiber. Several forms of bamboo can be used for reinforcement, such as the whole bamboo, sections, strips, and fibers. However various properties of bamboo are greatly influenced by its chemical composition.

The bamboo has already been used for various applications; however their use in polymer matrix composites has very rare.

Although natural fibers have many advantages, it has some limitations. The shortcomings of natural fibre reinforced composites have been their high moisture absorption, poor wettability and poor fibre-matrix adhesion. Therefore, chemical treatments are considerd in modifying the fiber surface properties. To this end, the present research work is undertaken to study the processing, characterization of short bamboo fiber reinforced epoxy composites. Attempts have also been made to explore the possible use of a natural fiber for making value added product and the effect of various surface treatments on the performance of composites.

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CHAPTER 2

LITERATURE SURVEY

This chapter provides the background information on the issues to be considered in the present research work and to focus the relevance of the present study. The purpose is also to present a thorough understanding of effect various chemical treatment on mechanical behavior of short fiber reinforced epoxy composites.

In fiber reinforced polymer composites, the reinforcing phase can either be fibrous or non-fibrous in nature and if the fibers are derived from natural resources like plants or some other living species, they are called natural fibers. Many investigations have been made on the potential of the natural fibres as reinforcements for composites. However, the experimental data of their mechanical properties, particularly when tested under different processing conditions, have shown inconsistent values in many cases [20-22]. The irregular characteristics of natural fibres are one of the main reasons for this. On the other hand, natural fibres are hydrophilic and many polymers are hydrophobic. This leads, in many cases, to problems associated with the interfacial properties of this type of composite [20-22]. Various treatments are used to improve the matrix-fibre adhesion in natural fibre reinforced composites.

Most of the studies made on natural fiber composites reveal that their mechanical properties are strongly influenced by a number of parameters such as volume fraction of the fibers, fiber length, fiber aspect ratio, fiber-matrix adhesion, fiber orientation and stress transfer at the interface. Therefore, both the matrix and fiber properties are important in improving mechanical properties of the composites. A number of investigations have been made on various natural fibers such as kenaf, hemp, flax, bamboo and jute to study the effect of these fibers on the mechanical properties of composite materials [23-26].

A strong fiber matrix interface bond is significant increasing mechanical properties due to effective transfer of stress from the matrix on to the fiber [27]. It has been reported by few investigators that the mechanical properties of the composites gets improved with increament in interfacial strength [28, 29,30]. The effect of surface treatment (silane coupling agent) on the interface performance of henequen fiber reinforced HDPE composites has been investigated [31]. It was reported that fiber surface silanization resulted in enhanced interfacial load transfer efficiency and silane treatment of cellulosic fibers can improve the interfacial strength. The mechanical properties of fiber reinforced composites can be improved by the peroxide induced graft copolymerization of polyethylene onto cellulose surfaces [32]. The effects of different chemical treatments on fiber reinforced polymer composites has been studied by few investigators [33-34]. The effect of chemical treatment on mechanical behaviour of banana fiber reinforced polyester composites has been studied and reported that the mechanical properties of different alkali treated banana fiber composites showed improved fiber matrix interactions [35]. The consequence of chemical treatment on the tensile and dynamic mechanical behaviour of short sisal fiber-reinforced LDPE has been studied and reported that the cardanol derivative of toluene di-isocyanate treatment lessened the hydrophilic nature of the sisal fiber and enhanced the tensile properties of the sisal-LDPE composites [36]. The effect of Benzoyl peroxide treatment on short sisal fiber reinforced polyethylene composites has been studied and reported that the improvement in tensile properties is occurring due to peroxide induced grafting [28]. Mu¨nker and Holtmann [37] studied different composite materials by reinforcing natural fibers (flax, ramie and curaua) in polymer matrices (polyester and polypropylene). It has been observed from their study that mechanical properties of natural fiber reinforced composites showed improvement with different coupling agents. Chemically treated natural fiber reinforced thermoplastic composites offered enhanced mechanical and physical properties under extreme conditions. Tensile properties such as tensile strength and tensile modulus of chemically treated short sisal fiber reinforced composites with different fiber loading has been studied [6]. Chemical treatments such as benzoylation, silane and peroxide treated flax fiber composites showed better physical and mechanical property owing to better adhesion adaptability between fibers and matrix [38]. Chemical treatment such as alkali treatment and MPP emulsion of jute fibers is found to be very good in enhancing the fiber matrix adhesion and thus mechanical properties in jute fiber reinforced PP composites [39]. Sreekala et al. [40] studied the mechanical behaviour of chemically treated oil palm fiber reinforced composites. They investigated the tensile stress-strain behavior of composites having 40% (by weight) fiber loading. The effect of chemical treatments such as mercerization, isocyanate, acrylation treatment and washing with alkaline solution of bagasse fiber on the tensile properties of bagasse-PP composites has been studied and it was observed from the study that chemical treatments improves the tensile properties of composites [41]. The effect of chemical treatment on impact behaviour of natural fiber reinforced polymer composites has been studied by few investigators [38, 42]. The effect of silane treatment on physical and mechanical properties of sisal fiber reinforced epoxy composites was reported by Bisanda and Ansell [43]. Yang et al. [44, 45] have studied the effect of compatibilizing agents on the mechanical properties and morphology of thermoplastic polymer composites filled with rice husk flour. Kalia at el. [46] reviewed the use of pretreated natural fibers in polymer matrix based composites.

2. 1 The knowledge gap

Through an exhaustive literature review it has been observed that although the literature is rich in the study of mechanical behavior of chemical treated natural fiber reinforced composites, however the effect of chemical treatment on short bamboo fiber reinforced polymers composites is hardly been found.

2.2 Objectives of the present research work

The knowledge gap in the existing literature review has helped to set the objectives of this research work which are outlined as follows:

1. Fabrication of a new class of epoxy based composites reinforced with short bamboo fibers.
2. Evaluation of mechanical properties such as flexural strength, impact strength, tensile strength and micro-hardness etc.
3. To study the influence of chemical treatments on mechanical behavior of short bamboo fiber reinforced epoxy composites.
4. To study the fracture surface morphology using SEM study.

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CHAPTER 3

MATERIALS AND METHODS

This chapter describes the particulars of processing of the composites and the experimental procedures followed for their characterization. The raw materials used in this research work are as follows:

1. Epoxy resin
2. Short bamboo fiber
3. Hardener

3.1 Preparation of composites

Short bamboo fibers which are taken as reinforcement is collected from local sources and the epoxy resin and the corresponding hardener (HY951) are supplied by Ciba Geigy India Ltd. A stainless steel mould having dimensions of 210 × 210 × 40 mm^3 is used for composite fabrication. The short bamboo fibers are mixed with epoxy resin by the simple mechanical stirring. Three different types of composites were fabricated: one set of composites without treatment; second set of composites with alkali treated fibers; and third set of composites with silane treated fibers. In alkali treatment, short bamboo fibers were immersed in 1% sodium hydroxide solution for one hour. Then the fibers washed thoroughly with water and finally with water containing a few drops of HCl to remove the final traces of alkali. Then the fibres were dried in an oven. In silane treatment, short bamboo fibers were allowed to react with silane by immersing in silane dissolved in a water acetone mixture for 2 h. After that the solution is decanted and the fibre is dried. Figure 2.1 shows short bamboo fiber and bamboo fiber reinforced epoxy composite and the detailed composition and designation of the composites are presented in Table 3.1. The cast of each composite is cured under a load of about 50 kg for 24 hours before it removed from the mould. Then this cast is post cured in the air for another 24 hours after removing out of the mould. Specimens of suitable dimension are cut using a diamond cutter for mechanical tests.

Figure 2.1 Short Bamboo Fiber and bamboo based composite.

Table 3.1 Composition and designation composites

Composites	Composition
SBFL-1	Epoxy+0wt% short bamboo fiber
SBFL-2	Epoxy+15wt% short bamboo fiber
SBFL-3	Epoxy+30wt% short bamboo fiber
SBFL-4	Epoxy+45wt% short bamboo fiber

3.2 Mechanical testing of composites

After fabrication of the composites, the test specimens were subjected to various mechanical tests as per ASTM standards. The tensile test and three-point flexural tests of composites were carried out using Instron 1195. The tensile test is generally performed on flat specimens. The most commonly used specimen geometries are the dog-bone specimen and straight-sided specimen with end tabs A uniaxial load is applied through both the ends. The ASTM standard test method for tensile properties of fiber resin composites has the designation D 3039-76. Micro-hardness measurement is done using a Vicker's micro-hardness tester. A right pyramid shape diamond indenter, having a square base and 136° angle between two opposite faces, is forced into the material under a load F. After removal of the load, the arithmetic mean L of the two diagonals X and Y of the indentation left on the surface of the material is calculated. In the present study, the load considered F = 1Kgf. The property of a material to resist the fracture under stress applied at high speed is known as Impact strength. Impact properties of the polymeric materials are related to the toughness of the material as a whole. Low velocity instrumented impact tests are carried out on composite specimens. The tests are done as per ASTM D 256 using an impact tester. The charpy impact testing machine has been used for measuring impact strength.

3.3 Scanning electron microscopy (SEM)

The surfaces of the composite specimens are examined directly by scanning electron microscope JEOL JSM-6480LV (Figure 3.2). The samples are washed, cleaned thoroughly, air-dried and are coated with 100 Å thick platinum in JEOL sputter ion coater and SEM was observed at 20 kV. Likewise all the composite samples with silver paste are mounted on stubs. To enhance the conductivity of the samples, vacuum evaporation of thin film of platinum is done onto them before the photomicrographs are taken.

Figure 3.3 SEM Set up

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CHAPTER 4

MECHANICAL CHRACTERISTICS OF COMPOSITES: RESULTS & DISCUSSION

This chapter presents the results of mechanical properties of short bamboo fiber reinforced composites. Also, the effect of fiber parameter such as fiber loading on mechanical behavior of short bamboo fiber reinforced epoxy composites is discussed here.

4.1 Mechanical characteristics of composites

The properties of the short bamboo fiber reinforced epoxy composites with different fiber loading under this investigation are presented in Table 4.1 and Table 4.2 respectively. The mechanical properties and physical properties of natural fibers differs largely depending on the chemical and structural composition, fiber type and growth conditions. Mechanical properties of plant fibers are much lower when compared to those of the most widely used competing reinforcing glass fibers. However, because of their low density, the specific properties (property-to-density ratio), strength, and stiffness of plant fibers are comparable to the values of glass fibers [7].

4.1.1 Effect of fiber loading on hardness of composites

Figure 4.1 shows hardness of untreated and treated short bamboo fiber reinforced epoxy composites. It untreated bamboo first increases up to 30wt% of fiber loading and then remains constant with increase in fiber loading up to 45wt%. The treated fiber composites show increase in hardness up to 45wt% fiber loading but alkali treated bamboo fiber showed more hardness than silane treatment as observed in Figure 4.1. As treated fibers composites exhibits higher hardness values than composites with untreated fiber reinforcements.

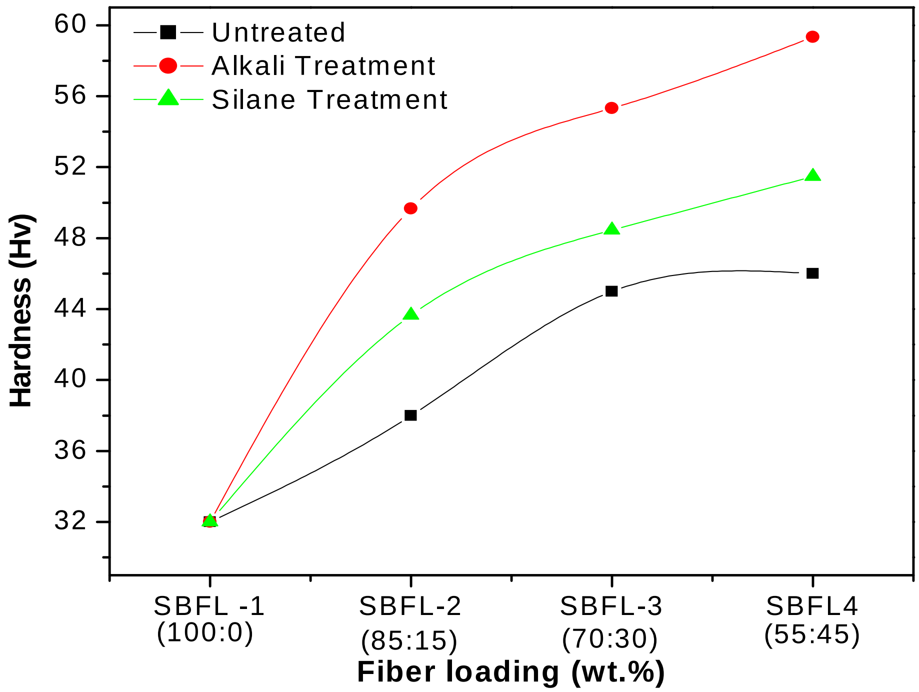


Figure 4.1 Effect of fiber loading on hardness of composites

4.1.2 Effect of fiber loading on tensile strength of composites

Tensile modulus and tensile strength measurements are among the most important indicatiors of strength in a material and are most widely specified property. Tensile modulus, an indication of the relative stiffness of a material, can be obtained from a stress strain diagram[47] .Tensile test is a measurement of the property of a material to withstand forces that tend to pull it apart and to determine to what extent the material stretches before breaking. Tensile strength and tensile modulus of matrix and randomly oriented untreated short bamboo fibre reinforced composites, aqueous NaOH (*Alkali Treatment*) and Silane Treatment (*3-amino propyl try ethoxy silane*) bamboo fibre composites with different fibre weight ratios i.e. 100:0, 85:15, 70:30 and 55:45 are presented in the Table 4.1. The tensile strength of short bamboo fiber /epoxy composites at different fibre loading are depicted in

Figure 4.2. It is clear that tensile strength of the composites increase with fibre loading. By the addition of 15wt% fibre loading, the strength is found to be increased to 20 % compared to neat epoxy system. A remarkable increase was observed in the case of modules also as shown in Figure 4.3. But the strain to failure is decreased as expected. The effect of different chemical treatments on tensile strength of short bamboo fiber /epoxy composites is given in Table 4.1. It is clear that in most cases an improvement is observed. The increase is significant in the case of silane treated fibre composite. The amino silane used in this work helps to bond with hydroxyl groups through hydrolyzable alkoxy group and amino group capable of interacting with the epoxy resin. During alkali treatment, waxes, hemicellulose and part of the lignin present on the fibre surface will be removed. The removal these compounds enhance the surface roughness, which allows mechanical interlocking. The formation of strong covalent bonds between the isocyanate and hydroxyl groups of cellulose lead to significant improvement in strength. The improvement in the case of resin impregnated fibre is associated with the increased wetting as well as due to the presence of strong epoxy bonds within the technical fibre. But it is found that modified silane treated bamboo fibre reduced the strength and modulus after 30wt% fiber loading.

Table 4.1 Tensile strength of untreated and treated short bamboo fiber reinforced composites

Composites	Untreated	Alkali Treatment (NaOH)	Silane Treatment (3-amino propyl try ethoxy silane)
SBFL-1	4.62	4.62	4.62
SBFL-2	7.59	15.14	7.95
SBFL-3	9.86	19.33	11.2
SBFL-4	10.48	13.667	12.77

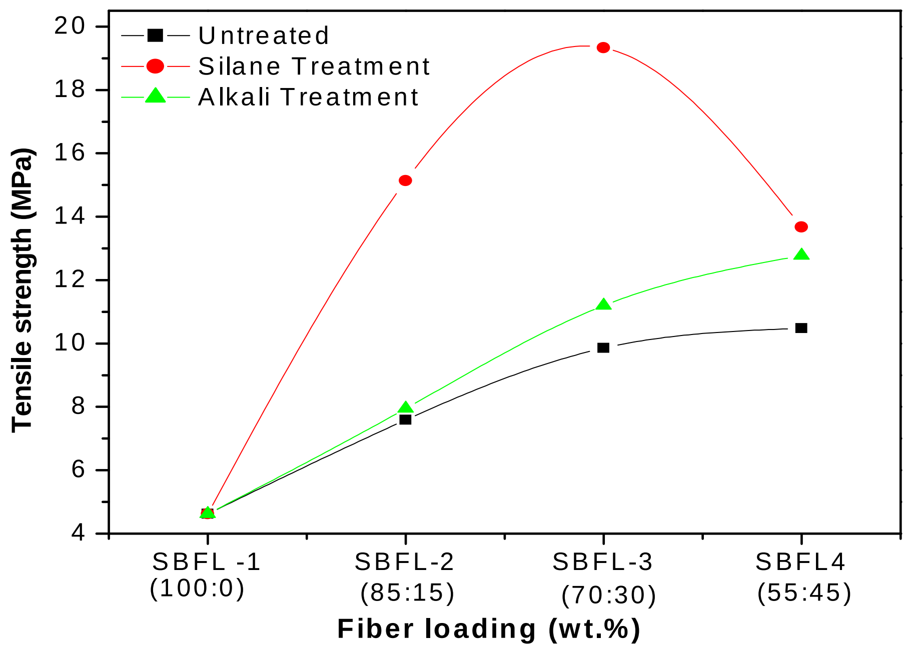


Figure 4.2 Effect of fiber loading on tensile strength of composites

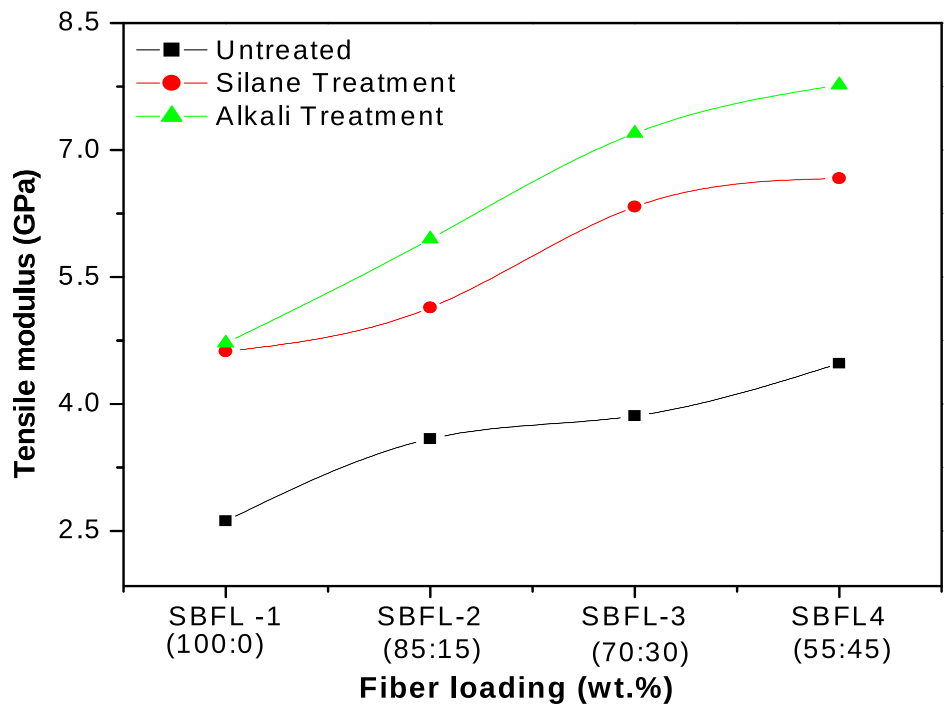


Figure 4.3 Effect of fiber loading on tensile modulus of composites

The improvements of tensile properties are due to the surface modification of bamboo fibres boiled with aqueous NaOH. Boiling the fibre with aqueous NaOH gives the surface of the fibre more roughness due to the removal of lignin and hemi cellulose. This increases the interface bonding between the fibre and the matrix.

4.1.3 Effect of fiber loading on flexural strength of composites

Flexural strength is one of the important mechanical properties of the composites. For a composite to be used as the structural materials it must possess higher flexural strength. The flexural strength values for different weight ratios of (i.e. i.e. 100:0, 85:15, 70:30 and 55:45) untreated, NaOH boiled and silane treatment composites are presented in Table 4.2. It is observed that the flexural strength for different fibre weight ratios of the composites is more when alkali boiled fibre is used in the composites.

Table 4.2 Flexural strength of untreated and treated short bamboo fiber reinforced composites

Composites	Untreated	Alkali Treatment (NaOH)	Silane Treatment (3-amino propyl try ethoxy silane)
SBFL-1	16.41	16.41	16.41
SBFL-2	25.70	27.86	26.1
SBFL-3	31.27	37.54	34.4
SBFL-4	19.93	28.05	24.15

From Table 4.3 it is clearly evident that the flexural strength composites are higher than those of the matrix. From the table it is also observed that the flexural strength increases with increase the fibre content in the composite as shown in Figure 4.4. The variation of flexural strength of untreated, aqueous NaOH and silane treatment boiled bamboo fiber composites with different weight ratios of fibres in composites are presented in Figure 4.4. It is clearly seen in the figure that flexural strength increases with carbon fibre content. From the figure it is observed that the flexural properties of the bamboo fibre reinforced composites were considerably lower than those for the long bamboo fibre reinforced composites and hence to improve the properties treatment is generally required for short bamboo fiber reinforced composites. From the figures it is also observed that aqueous NaOH bamboo fiber reinforced composites have higher flexural strength than untreated bamboo fiber reinforced composites. A possible improvement in the bonding between the reinforcement and the matrix is done by the alkali treatment which increased the flexural properties of the composites. The reason for this is that the alkali treatment improved the adhesive property of bamboo fibre surface by extruding hemi cellulose, thereby producing rough surface topography [47].

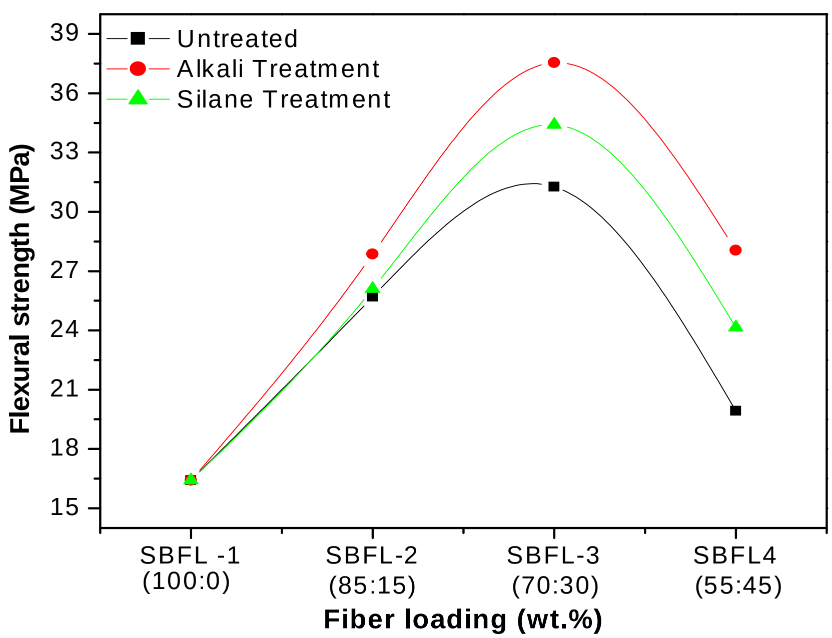


Figure 4.4 Effect of fiber loading on flexural strength of composites

4.1.4 Effect of fiber loading on impact strength of composites

Impact strength exemplifies the toughness of materials under high strain rate deformation. Figure 4.5 shows the variation of impact strength of untreated and treated bamboo fiber reinforced epoxy composites. The impact strength of composites is not greatly improved by both alkali-treated and silane treatment. Although the bending strength of alkali treated bamboo composites are higher than that of silane treatment, there is little difference in impact strength between both composites. The effect of fiber reinforcement on the impact strength of composites is more complicated than bending and tensile strengths since the impact strength is attributed to the energy consumption during failure. Higher interfacial strength does not always derive higher impact strength. Medium or lower interfacial strength is sometimes appropriate to increase the dissipating energy during fracture due to fiber pull-out. In this case, longer fibers are preferable.

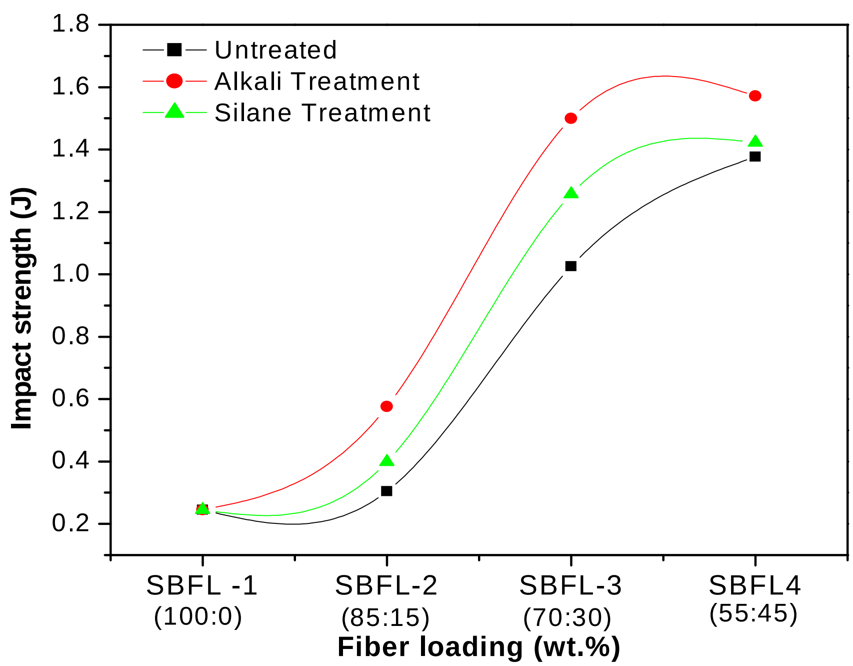
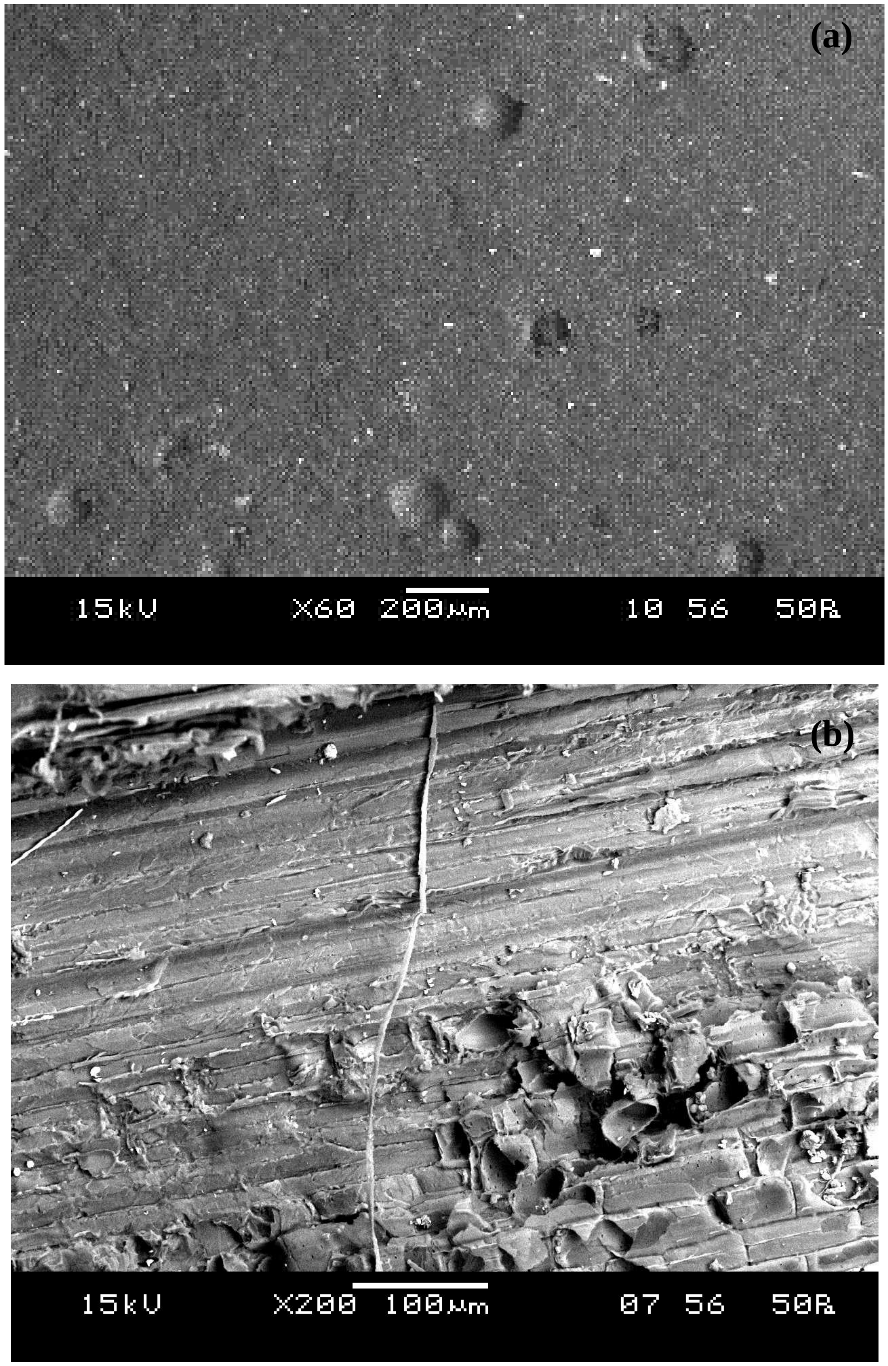


Figure 4.5 Effect of fiber loading on impact strength of composites

4.2 Surface morphology of the composites

Figure 4.6(a) shows the fiber reinforced epoxy composite without tensile test sample. It is observed from the figure that the surface looks very smooth and lesser void content as shown on the upper surface of the composite sample. On applying tensile load on the 45wt% of bamboo fiber reinforced epoxy composite the fractured surface of composite shows breaking of matrix material under initial loading condition (Figure 4.6(b)). This is due to the fact that without fibers to check the crack growth upon external loading, the crack propagates in an unstable manner. Besides, it is also observed that there is matrix plastic deformation near the crack tip, which contributes to plastic zone generation in the material. However, with the increase in tensile load up to yield point relatively long extruding fibres can be ob- served, which is depicted by fibre pullout as shown in Figure 4.6(c). It is an indication of crack deflection, where the crack path is changed by the fibre and directed along the fibre surface. This leads to fibre debonding, which is an indication of matrix separation around the fibres as crack front intersects the fibre/matrix interface. Subsequently, it causes fibre pull-out. In this case, energy is dissipated by shear. The effect of treating the fibre with of NaOH is still poor as the fibre may not bond well with the matrix due to the present of impurities. Thus, during the pullout, the fibre was slightly pulled out where the impurities are present on the specimen top surface; Figure 4.9(c). The proposed pullout mechanism for NaOH fibre treatment is presented in Figure 4.9(c). Treating the fibre with 6% of NaOH resulted in superior interfacial adhesion strength with the polyester matrix. This finding is in agreement in most researches done involving the usage of NaOH as fibre treatment [48, 49].


(a)
15kV X60 200µm 10 56 50R
(b)
15kV X200 100µm 07 56 50R

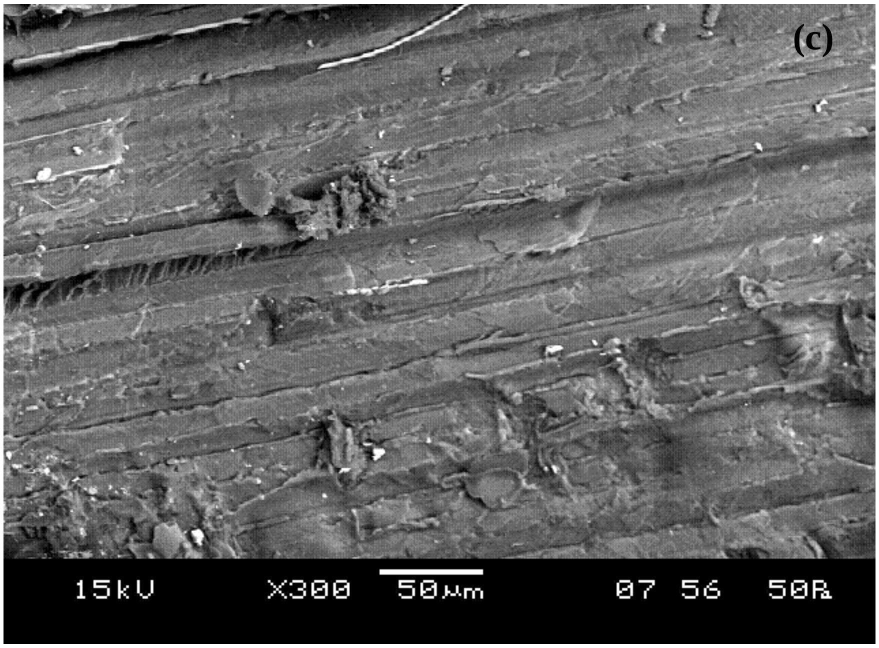


Figure 4.6 Scanning electron micrographs of bamboo fiber reinforced epoxy composite specimens after tensile testing.

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CHAPTER 5
CONCLUSIONS

The experimental investigation on the effect of chemical treatment on mechanical behavior of short bamboo fiber reinforced epoxy composites leads to the following conclusions obtained from this study are as follows:

1. The successful fabrications of a new class of epoxy based composites reinforced with short bamboo fibers have been done.
2. It has been noticed that the mechanical properties of the composites such as hardness, tensile strength, flexural strength and impact strength etc. of the composites are also greatly influenced by the chemical treatments.
3. The mechanical properties such as hardness, tensile strength, tensile modulus, flexural strength and impact strength of untreated, treated NaOH and silane treatment bamboo fiber composites are studied. The variation of tensile strength, tensile modulus and flexural properties of these composites are studied by different weight ratios. The chemical resistance tests of these composites were also studied.
4. It is observed that, there is enhancement in these tensile, modulus and flexural properties with increases fibre loading in the composites. The effect of alkali treatment of bamboo fibres on the tensile, moduls and flexural properties have also been studied and found that increase in properties by alkali treatment and silane treatment. It is observed that both the treated bamboo fibre reinforced composites showed superior tensile, modulus and flexural properties than untreated bamboo fiber composites.
5. This is due to the fact that alkali treatment enhances the fibre surface adhesion property by removing hemi-cellulose, thereby producing rough

surface topography. This topography offers better fibre-matrix interface adhesion and an increase in mechanical properties.

6. 1. Scope for future work

There is a very wide scope for future scholars to explore this area of research. This work can be further extended to study other aspects of such as use of other types of chemical treatments for surface modification of bamboo fiber reinforced polymer composites and evaluation of their mechanical behavior and the resulting experimental findings can be similarly analyzed.

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